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AN EXPERIMENTAL STUDY AND STATISTICAL ANALYSIS OF TIME STUDY RATING ABILITY OF OPERATIONS ON FILM AS AGAINST RATING THE ACTUAL OPERATION

A THESIS

Presented to

the Faculty of the Graduate Division

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Approved:

Date Approved by Chairman: 2 June 1956

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ABSTRACT

The primary purpose of this research is to investigate the difference between time study rating of actual operations and the rating of films of the operations to determine if there is a significant difference.

By using two typical industrial operations and experiment was run with 21 experienced time study engineers rating first the actual operation and then films of the operations. The films were made at the same time as the original rating of the actual operation so as to duplicate on film the exact motions and performance that was initially rated. These films were rated at a later session by the time study engineers. The film presentation was made at the same speed as the filming speed of the camera, namely 1,000 frames a minute. This speed was maintained during the film rating session by the use of a Strobo-Tachometer synchronized on the projector sprocket. Sixty-four film loops were made and rated by the 21 time study engineers.

Two approaches were made to analyze the data gathered. One technique was that of testing the sample means of the operation against the sample means of the films, to see whether there was any significant difference by using Student's t-test. The second technique was a factorial analysis of variance.

Based on the results of the statistical analysis of the data of this research and within the experimental limitations the general conclusions reached were as follows:

1. There is some difference in rating of films as compared to rating of actual operations. However, there was insufficient evidence to say conclusively that this difference was significant.
2. Rating of film presentations is likely to result in a slightly higher average rating error than rating of the actual operation.
3. The differences between rating film and rating of the actual operation is likely to be related to the particular operations involved.
4. Individual raters are likely to perform differently in their rating of film as compared with actual operations.
5. The experimental subjects displayed a tendency to over-rate slow performances and to under-rate fast performances.

It is recommended that time study engineers receive rating training on the factory floor with an experienced time study engineer instead of in the class room using rating films. This would give more realistic training and improve accuracy of rating.

It is also suggested that further analysis of this problem would be profitable.

CHAPTER I

INTRODUCTION

Since the time of Fredrick W. Taylor, stop-watch time study has been used to set time standards. And today the greatest number of standards are still set by making time studies. Such setting of standards requires that the observer rate the operator under observation in order that the observed time can be converted into normal time. It is unfortunate that there is no way to establish a time standard for an operation without the judgment of the time study man entering into the process.

The importance of rating cannot be underestimated even though it is considered one of the weakest aspects of present day time study. Phil Carrol expresses his opinion about rating by saying, "Rating is the (most) important step in time study procedure, if any one part may be so designated. The rating is the key which permits the translation of an abstract time record into equitable incentive standards."(1)[1] The fact that an operator under observation does not necessarily work at "normal" performance, but above and below

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[1]Numbers in parantheses refer to references listed in the Bibliography.

normal performance, requires that the time study man evaluate the rate of pace or rate of activity of the operator when making the time study.

Because performance rating is a subjective procedure involving the element of judgment, it has often become a matter of controversy. Until some objective method is developed, we should make the best use of the subjective approach that we presently have and attempt to improve it.

According to Barnes, "Rating is that process during which the time study man compares the performance (speed or tempo) of the operator under observation with the observer's own concept of normal performance."(2)

An even better definition is given by Emerzian when he says,

> Rating is a *technique for* equating differences in operator performance. To arrive at a rating, the time study observer goes through the following mental process. First, he makes a gross judgment which places the observed performance either above or below normal or standard. His second judgment indicates the precise position along the rating scale which properly evaluates the numerical difference between standard and actual performance. The second and final judgment estimates by how much the observed performance differs from normal performance.(3)

For the purpose of this thesis, rating will be that process during which the time study engineer compares the rate of pace or rate of activity of the operator under consideration to his own mental concept of standard and determines in his own mind whether it is above or below standard performance and by how many percentage points.

Need for Improvement.--Workers usually do not work at normal pace. Time study men agree on what is above or below normal but do not always agree on how much above or below normal an operator is working when under observation. The accuracy of standards developed from time studies always depends upon the time study engineer's judgment. Generally the time study engineer tends to be conservative or to hedge in the direction of normal. He usually under-rates fast performances and over-rates slow performances.

The need for improvement is brought out in the study of Cohen and Strauss in which film studies were made of 21 experienced operators working on a man-controlled operation.(4) Each operator was then rated by three trained observers using the Westinghouse leveling method. When their pooled rating judgment was applied to the observed times, it was found that the rated times varied from .05904 to .12470 minutes.

In another study Quick, Koehler and Shea describe an experiment in which one hundred time study men from different industries were asked to establish a production standard for a simple bolt and washer assembly from a film record.(5) In all, 62 different standards were recommended, with an overall variation of 61 per cent. These results were used by these writers to bolster their argument that rating is one of the weakest aspects of time study. Such studies indicate that efforts to improve the accuracy of time study ratings should be concentrated upon the factor of judgment.

As Phil Carrol says, "Judgment is a human attribute, subject to the variations of the human being, but judgment can be trained whereas the actions of the human being as recorded on a time study are unpredictable by any scientific formula."(6) The only way to improve the accuracy of a standard is through improving the rating ability of time study engineers.

The Problem of Accuracy in Rating.--A bibliographical search reveals that since the beginning of World War II there has been great concern among time study experts regarding the matter of rating, and they have suggested various means of improving rating ability.

Buffa suggests that what is needed is a national performance standard which can be kept by the National Bureau of Standards. He further suggests that the best means available today of recording and fixing basic standards of performance is the motion picture film. He states that, "The confusion which surrounds performance rating results from the fact that basic standards are not uniform between different plants, the basic standard usually is not recorded and rating scales are used which are different but appear to be the same."(7)

Speakman also recognizes the need for accuracy but suggests a somewhat different approach. He says,

> Time study is not just a combination of the stop watch and slide rule. It is obvious that it must stand or fall on the inherent sense of judgment on the part of the observer. The rating factor is a contentious one and the most difficult to substantiate. Obviously, the ability to rate within comparatively fine limits of accuracy is not acquired easily and can be achieved only by experience and constant practice.(8)

Anson in his study found that there were irregularities in the rating films such as change in method, short scenes (below 5 seconds), and low rates of working that affected the rating ability of the time study engineers.(9)

Errors in rating result from the use of different methods and different criteria. Some observers rate on speed alone, others on speed and skill, while others say that they take into account speed, effort and skill. According to Speakman, "There is only one criterion for rating and that is effective effort."(10)

<u>Previous Research</u>.-- Carson made a study analyzing the ratings of six experienced time study men who worked for a company which conducted one-hour rating sessions each week. The results of the study showed that these men did not differ significantly from each other in the level of their ratings or in standard deviations. The standard deviation of single independent ratings was 6.67 per cent. He concludes that a group of time study men trained alike in evaluating speed of work will rate film loops alike. He also found that regular use of practice rating sessions reduced the error in rating and develops more consistency between men both as to vari ability of ratings and mean or level of ratings.(11)

Margolin reported on an experiment with a group of industrial engineers at Purdue University. The engineers rated elements and cycles of film loops of five different operations that had been filmed previously by Peter W. Schwab and then rated an operator performing these same five operations. A motion picture was taken of the operation while the rating of the actual operation was being performed. After processing, the films were analyzed for actual time values. These values were then used as the standard by which to evaluate the ratings of the operations. His conclusions were that ratings are more consistent and accurate when made from motion pictures than when made from the actual performance of the operator.(12)

Nadler's experiment was similar in many respects to Margolin's. Four operations were chosen and presented on film at different speeds to be rated by trained time study engineers. Then the actual operations were presented and rated by the engineers as the operator regulated his speed by the use of an electric pick-up of a metronome. The operator performed the same jobs duplicating as nearly as possible the speed of his previously filmed performance. Nadler's findings were just the opposite of those of Margolin, for they showed a tendency within the limits of the experimental situation for the actual operator to be rated more consistently and accurately than the films of the operation.(13)

<u>Conclusions</u>.--Results in the last two studies cited are questionable in the light of the limits of the experiments. In the first, Margolin used films made at a different time and a different place from that of the actual operation. Nadler went a step further in that he used a metronome to pace his operator, but he too failed to duplicate in the actual operation the motions and pace of the filmed operation. As did Margolin, Nadler also assumed that the filmed operation was essentially the same as the real operation.

CHAPTER II

OBJECTIVE

Many doubts have been expressed about the use of films in industry for the purpose of time study rating, training, and checking time study men. However, in the last few years we have seen the increasing use of film for the purposes mentioned above. Because of doubts and fears as to the validity of their use it is felt that an investigation of the supposed differences of rating films and rating the actual operator is most desirable.

The purpose of this thesis is to study several typical industrial operations and films of these operations in order to determine:

1. Significant difference in rating operations as against rating films of the operations.
2. Significant difference in consistency[1] in rating operations as against rating films of the operations.

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[1]Consistency means identical performances are rated the same every time.

CHAPTER III

EXPERIMENTAL PROCEDURE

Selecting the Operations.--The selection of a job for this experiment depended upon three considerations. The first was its adaptability to variance in the speed at which it could be performed. The second consideration was that it involved sharp, clear, distinctive motions and elements. This second requirement was needed to eliminate any confusion as to the beginning and end points of the operation. This limitation then led to a third consideration, namely, that the job would include enough motion of the arms and hands so that the operation would not be classified as a special type of job such as assembling very small parts in which only the fingers or hand takes part. On the basis of the above mentioned limitations the following two operations were chosen:

1. Air Conditioner Front Assembly.
2. Cold Rolled Steel Plate Assembly.

Pictures of the above operations may be seen in Appendix III.

The first operation (hereafter called operation "A") was furnished by Dr. Dale Jones of the Industrial Engineering Department at Georgia Institute of Technology. Some modification was required to make the assembly a desirable operation.

A fixture of plywood was made to hold the air conditioner frame during the assembly operation so that it would not move or cause the operator to fumble. This operation consisted of assembling 4 grills into a frame, installing four inserts, glueing on four knobs, and setting aside the finished assembly. Figure 1 shows the workplace layout and the position of the operator for operation "A".

The second operation (hereafter called operation "B"), devised by the author, consisted of two cold rolled steel plates assembled with a bolt, washer, and nut. A jig was designed and welded to assist in assembling two units at one time. A Black and Decker screw gun was suspended with springs 12 inches above the jig. The operator reached for the gun as needed and positioned it over the nut to be run up. This gun was actuated when downward pressure was applied. Figure 2 shows the workplace layout and the position of the operator for operation "B". The elemental description of both operations may be seen in Appendix I.

A standard of 0.500 of a minute for operation "A" was established by Dr. Dale Jones.(14) For operation "B" the standard was established by Methods-Time Measurement. The Methods-Time Measurement analysis may be seen in Appendix II.

Selecting the Operator.--The selection of an operator called for certain requirements. First, he had to have a definite interest in the type of work being done and in what was to

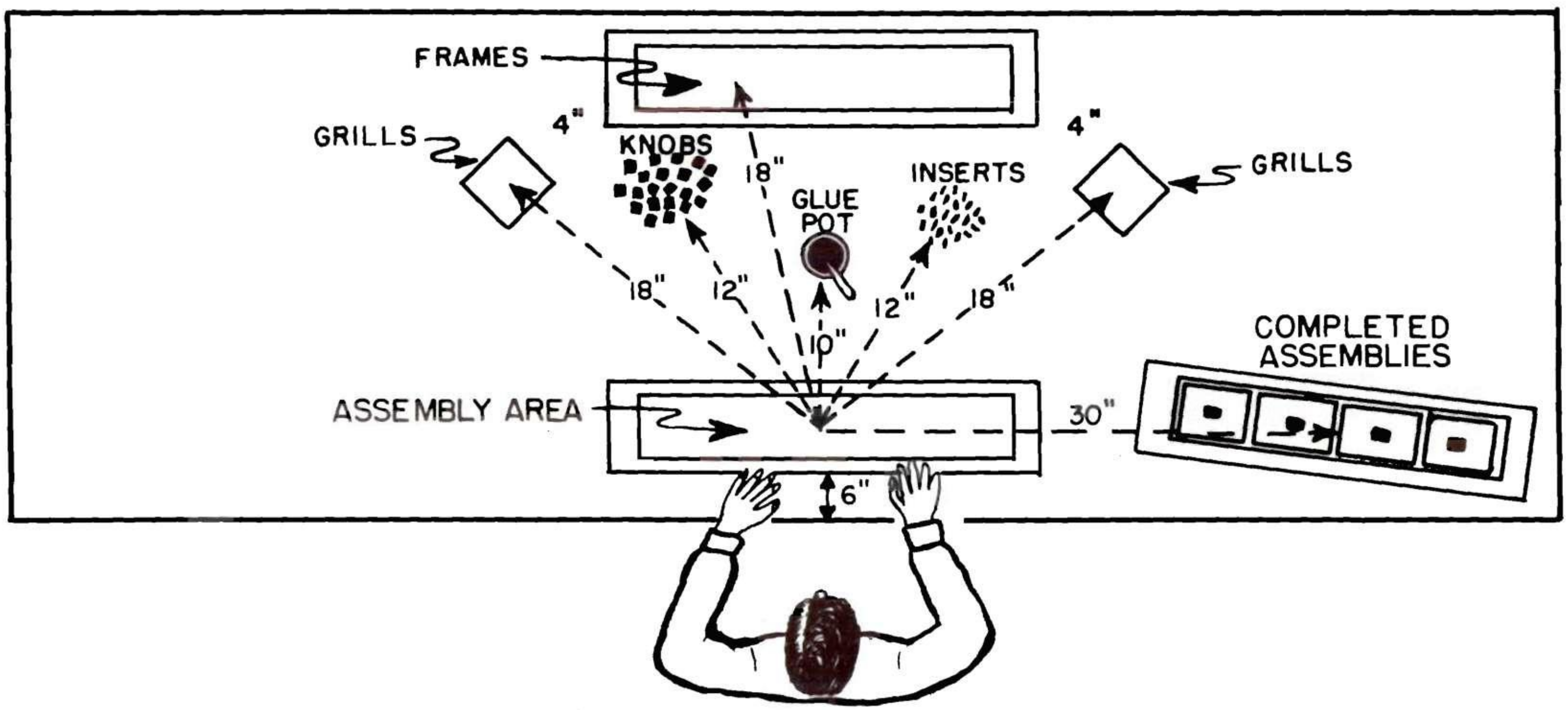

FIGURE 1. WORK PLACE LAYOUT OPERATION "A"

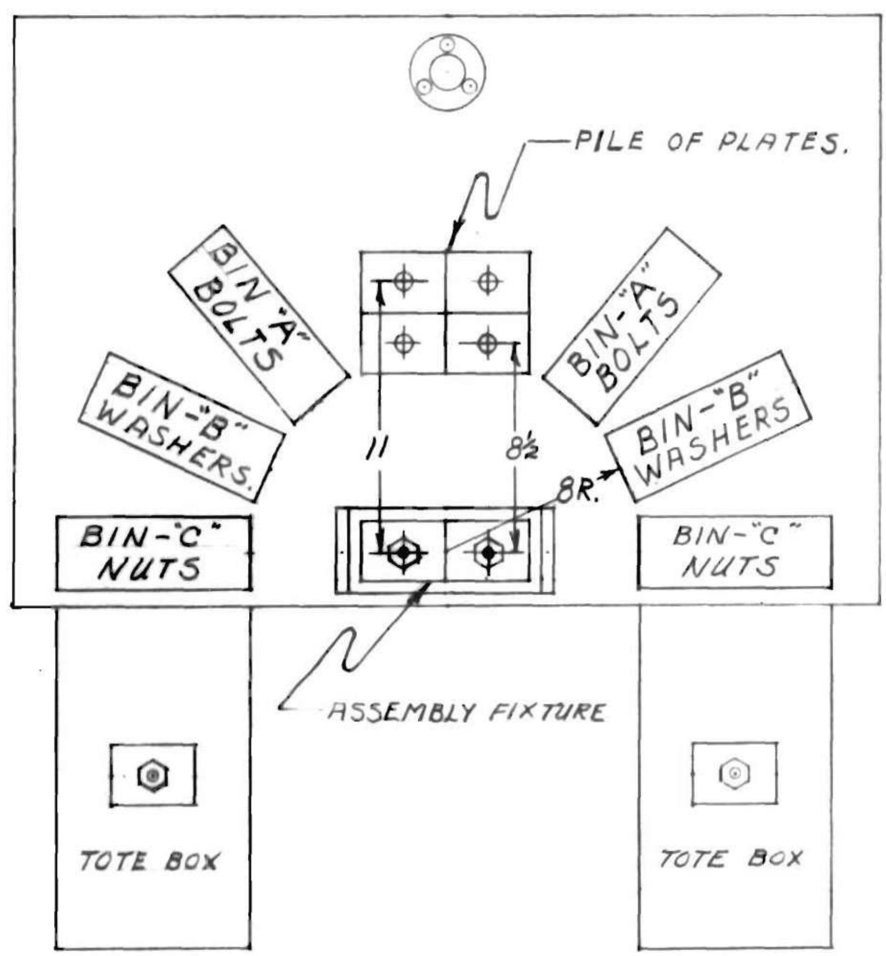

FIGURE 2. WORK PLACE LAYOUT OPERATION "B"

accomplished. A person not at all in sympathy with the research could not be depended upon for wholehearted cooperation. Secondly, the person selected had to have the time available to practice and become acquainted with the jobs selected. The author was able to find a person that met these requirements.

Training the Operator.--The operator was given a list of the elements of each operation and shown by actual demonstration the method of performing the job with special emphasis on the motion patterns. Then followed for two weeks a period of practice and training, the main purpose being to acquaint the operator with the jobs and allow him to obtain the experience and improvement of skill needed. The operator performed the operations at his minimum and maximum speed or rate of activity and at ranges in between the limits 50 per cent to 130 per cent. This type of training continued until at last it was felt that the operator had smoothed out all irregularities in his performance of the operations at the different speeds. The operator received additional training because of the fact that the first two filming sessions were not successful and two additional ones were required to complete the experiment.

Taking of Motion Pictures.--Pictures of the operations were taken with an Eastman Kodak Cine Special II Camera, equipped with a 15 millimeter, f-2.5 lens and driven by a Bodine synchronus motor at 1,000 frames per minute. The camera was mounted on an adjustable tripod at a height of about five feet and was set fifteen feet from the working area for both operations.

Two reflectors with No. 2 photofloods and one boom spot light were used to illuminate the operation and the operator during filming to give a good clear picture when the films were developed.

Motion pictures of 16 cycles were made of each operation at the second session for the first group of engineers. The first session was not a success because the lens came loose in the mount and caused the pictures to be out of focus. The author originally planned to take eight cycles of each operation but to conserve time and not to prolong the experiment 16 cycles were taken.

At the first session held for the second group of engineers, the film jumped the sprocket and bunched up inside the camera ruining all but three film loops. At the second session for the second group of engineers, motion pictures of 16 cycles were made of each operation.

Analysis of Film.--All of the film was carefully edited so that all cycles were free from major variations in method and obvious fumbles. In order to have a minimum number of breaks in the continuity of motion, minor variations in method and lesses fumbles were allowed to remain in the film.

The films in their final form were made up of two reels for the first group of engineers and two reels for the second group of engineers. The first reel contained 15 cycles of operation "A", and the second reel contained 15 cycles of operation "B". The third reel contained 17 cycles of operation "A", and the fourth reel contained 17 cycles of operation "B".

Collection of Data.--This thesis experiment was performed at Lockheed Aircraft Corporation, Marietta, Georgia, as a "Rating Performance Project." All methods and time study engineers have regular monthly rating classes. This experiment took the place of the classes for the months of August, September, and October, 1955.

At the first session time was allowed for presentation of the jobs so that the engineers might become familiar with them. For training purposes and warm-up period the operator went through eight continuous cycles on operation "A" and seven continuous cycles on operation "B" while the engineers rated each cycle. While the operator was going through the warm-up period, the camera was set up to the right of the operator at an angle of about 45 degrees.

Before the rating of the actual operation began, the objective of the experiment and the procedure to be followed were explained. Demonstrations of the standard methods on each operation were given and elemental endings discussed. Since the majority of the engineers present stated that they had not rated elements as short as those embodied in the operations, it was decided that they should rate complete cycles. All engineers rated the cycles, using the 100 per cent normal method. In addition, the engineers were asked to:

1. Strive to make each rating to the best of their ability and keep as much attention on the operator as possible.

2. Refrain from talking about ratings among themselves during the rating sessions.

3. Make a decision concerning what the rating should be and to record this on the rating form quickly so they could observe and rate the next cycle.

Motion pictures were made at the very same instant the engineers were rating the operations, the purpose being to reproduce on film the exact duplicate of job and motions so that there would be a true comparison between data gathered at the first session (rating operations) and at the second sessions (rating films).

Before the film loops for each reel were spliced together, they were numbered and placed on a table. The author's son picked up one film loop at a time in random order until all had been selected. This was done so that no set sequence of pace could possibly influence the raters. Table 1 and Table 2 show the actual sequence of films at the rating film sessions for operations "A" and "B".

All films were shown on a Bell and Howell 750 watt rating projector. The projector was synchronized to 1,000 frames per minute by using a Strobo-Tachometer Model No. 351-A made by Electronic Measurements Company, Red Bank, New Jersey. While the operator was performing the operations for the training period, the projector and strobo-tachometer were turned on and allowed to warm up for more than 15 minutes just before projection of films. The strobo-tachometer was shone on the sprocket wheel of the projector, and the built-in rheostat was adjusted when necessary to keep the reel standing still so that the projector was always operating at 1,000 frames per minute.

To make a smooth, continuous projection of the films, at the beginning of each loop the author spliced a title, "Rate Next Cycle" and at the end of the loop a title, "Record Your Rating." The first title occupied 40 frames while the second occupied 140 frames. This gave the engineers adequate time to record their readings and to get ready for the next cycle. As the projector started, the lights were turned off. When the first frame of "Record Your Rating" appeared on the screen, the lights were turned on for the 140 frames to allow the engineers to record their ratings on the film rating form (Figure 3). The man at the switch turned off the lights when "Rate Next Cycle" again appeared on the screen.

TABLE 1

OPERATION "A"

SEQUENCE OF FILMS

ORDER OF PROJECTION OF RATING FILMS	CYCLE TIME	ORDER OF PROJECTION OF RATING FILMS	CYCLE TIME
7	.937	2	.487
8	.428	1	.560
1	.648	3	.504
9	.568	14	.467
14	.754	4	.435
11	.612	10	.397
4	.478	7	.408
13	.510	11	.645
15	.553	2	.731
3	.715	13	.396
6	.553	1	.623
5	.598	6	.711
12	.475	8	.834
2	.545	9	.561
10	.553	5	.531
		3	.435
		12	.776

TABLE 2

OPERATION "B"

SEQUENCE OF FILMS

ORDER OF PROJECTION OF RATING FILMS	CYCLE TIME	ORDER OF PROJECTION OF RATING FILMS	CYCLE TIME
6	.393	10	.628
1	.391	9	.390
11	.463	2	.548
10	.350	3	.422
13	.337	6	.483
4	.316	14	.365
14	.475	17	.299
9	.289	7	.361
3	.415	1	.310
8	.567	16	.409
12	.306	5	.455
2	.339	13	.262
5	.606	12	.372
15	.367	4	.257
7	.321	8	.461
		15	.451
		11	.683

RATING FORM

AIR CONDITIONER FRONT ASSEMBLY

FILM	CYCLE NO.	RATING
	1	50
	2	130
	3	105
	4	100
	5	80
	6	95
	7	110
	8	100
	9	105
	10	80
	11	115
	12	110
	13	130
	14	120
	15	105
	16	
	17	
	18	
	19	
	20	

COLD ROLLED STEEL PLATE ASSEMBLY

FILM	CYCLE NO.	RATING
	1	105
	2	130
	3	95
	4	120
	5	125
	6	115
	7	100
	8	140
	9	100
	10	65
	11	140
	12	125
	13	70
	14	115
	15	140
	16	
	17	
	18	
	19	
	20	

Time study experience (regularly taking time studies)

Years 3 Months 0

This information will be kept confidential and will not be released outside of Lockheed unless coded so as not to reveal the persons identity.

Time study engineer__________ Date 10-13-55

FIGURE 3.

CHAPTER IV

EVALUATION OF DATA

Two approaches were made to analyze the data gathered from the experiment. One technique was that of testing the sample means of the operation against the sample means of the films to see whether there was any significant difference by using Student's t-test. The second technique was a factorial analysis of variance.

For this analysis 15 cycles were used for each engineer in order to simplify the calcu.ations of analysis of variance.

The standard deviation for each such set of 15 ratings, one for the actual operation and one for the film, was calculated by use of the equations.

$$S_o = \sqrt{\frac{\bar{X}_o - \bar{X}_o}{n - 1}} \quad \text{and} \quad S_f = \sqrt{\frac{X_f - \bar{X}_f}{n - 1}}$$

where S_o is the unbiased estimate of the standard deviation of the 15 ratings for the actual operation, S_f is the unbiased estimate of the standard deviation of the 15 ratings for the films, X_o and X_f are the assigned ratings, $\bar{X}_o$ and $\bar{X}_f$ are the systematic errors of the operation and films respectively and n is the number of ratings (in this case 15).

All ratings were converted to a percentage of the correct rating. This was done by the formula

$$\% \text{ rating error} = \frac{\text{observed rating} - \text{actual rating}}{\text{actual rating}} \times 100$$

This converted figure was used for the rest of the analysis. The purpose of the conversion was to make comparable an individual's ratings, regardless of the level of production rated.

The converted ratings were posted to analysis sheets. One of the analysis sheets contained all of the ratings made by one engineer for operation "A"; and the other contained all ratings made for operation "B".

The first hypothesis tested was the hypothesis of no difference; mathematically it stated that the mean of the actual operation ratings was equal to the mean of the film ratings. In terms of the present problem it stated that the sum of the individual actual operation ratings was not significantly different from the sum of the individual film ratings. Stating the problem as a null hypothesis assumed that both means had come from a random sampling of normally distributed populations having a common mean value.

The analysis of variances was applied to both operations to determine the variation of ratings caused by the three main factors and to what extent each of them caused the variation. The three main factors were the operations, the environment (whether rating actual operations or rating films), and the time study engineers. The basic data used for this analysis is presented in Table 3.

The analysis of variance(15) is a procedure by which the sum of the squares is calculated for the effect of each main factor, the first order interaction between these factors, and the second order interactions between these factors. The sum of squares for each main factor and interactions was divided by their degrees of freedom to form the mean squares. These mean squares were used to form ratios of variance with the residual variance and these ratios were tested for significance by the Fisher F test.

TABLE 3

CODED DATA FOR ANALYSIS OF VARIANCE

Opera- tions	Environ- ment	RATERS R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}
O_1	E_1	-483	532	-385	709	734	-237	-153	-519	1102	-689	-1058
	E_2	-121	417	1212	669	300	-466	-292	221	672	-541	905
O_2	E_1	-517	-228	1352	510	74	664	-242	484	1363	465	-180
	E_2	1624	1069	1380	922	845	148	430	497	1956	306	689

		R_{12}	R_{13}	R_{14}	R_{15}	R_{16}	R_{17}	R_{18}	R_{19}	R_{20}	R_{21}
O_1	E_1	-409	-514	-849	-940	541	-1519	-716	-1478	-995	-707
	E_2	40	-496	-201	-1638	-1103	-489	-356	-562	-744	-475
O_2	E_1	-805	-246	-336	-170	-770	1131	716	-771	-43	-157
	E_2	-761	-114	356	1097	1156	2125	2010	488	-85	636

Original Data = (Coded Data $\neq$ 20.00 x 10^{-2}

Example -483 = 15.17% Rating Error
O_1 = Operation "A"
O_2 = Operation "B"
E_1 = Rating Actual Operations Only
E_2 = Rating Films Only
R = Time Study Engineers

CHAPTER V

RESULTS

Using the equation given in the proceding section, the mean and standard deviation were calculated for operations "A" and "B". Table 4 and Table 5 show the systematic error and standard deviation for the group were less on ratings of the actual operations than on ratings of the films.

In making the Student's t-test on 21 engineers for operation "A" and operation "B" the null hypothesis was accepted 37 times and rejected five times at the five per cent level of significance. This indicates that there is no significant difference in the means of the ratings on film as against the ratings on the operation in 88.1 per cent of the cases. In 11.9 per cent of the cases there is a significant difference in the means of the ratings on actual operations as against films of the operation. It can be concluded that there is evidences of some difference between the actual operations and the films.

Table 6 shows the results from the analysis of variance. It shows that the systematic error varied mainly due to the effect of R (the time-study engineers). This factor was significant at the 0.1 per cent level, which indicates that there is only one chance in a thousand that variations due to this factor could have happened by chance. The variation caused by raters indicates that there was a considerable difference of opinion among the engineers in judging how far away the observed performance was from normal.

To a lesser significance level the factors O (operations), OR (the interaction between the operations and the raters), ER (the interaction between environment and the raters) contributed variances. These factors are significant at a level of one per cent. The O factor indicates that on different operations the engineers rate differently. This is evident from the large systematic error and standard deviation on operation "B". The first order interaction OR indicates that if engineers were to rate various operations, the accuracy would vary for different operations and among different engineers. Similarly, ER interaction indicates that accuracy would vary for different environments and among different engineers. From Tables 4 and 5 it is evident that the systematic error is less on the actual operations than on the films. This must be true because the interaction is significant at the one per cent level, showing the difference in the error to be dependent upon the environment.

The E factor shows a five per cent significance level, but it does indicate some difference between the actual operations and the films.

The OE interaction was not significant.

TABLE 4

SYSTEMATIC ERROR AND STANDARD DEVIATION OF

PER CENT RATING ERROR FOR OPERATION "A"

ENGI-NEER	SYSTEMATIC ERROR OPERATION	SYSTEMATIC ERROR FILM	SIG. LEVEL BETWEEN MEANS	STANDARD DEVIATION OPERATION	STANDARD DEVIATION FILM
A	15.90	20.40	.15	15.63	21.57
B	12.65	23.01	.01	10.44	10.10
C	14.86	15.03	.90	9.13	9.30
D	14.81	22.22	.06	9.23	15.10
E	9.42	29.05	.001	12.89	13.29
F	25.32	25.14	.90	16.42	12.31
G	13.10	14.59	.67	10.36	9.57
H	10.59	3.61	.26	13.24	10.83
I	15.75	32.12	.01	13.02	12.49
J	12.84	16.43	.44	12.92	22.21
K	31.02	26.73	.35	10.33	14.09
L	10.05	12.56	.67	11.46	16.96
M	17.63	15.30	.60	11.04	10.76
N	4.80	12.79	.06	11.48	12.49
O	12.90	13.31	.90	8.55	10.07
R	12.92	15.24	.68	14.34	14.35
S	18.46	17.08	.78	14.26	11.41
T	11.50	17.98	.11	11.60	9.56
U	14.42	8.96	.27	15.64	13.94
V	15.16	19.48	.86	6.11	12.31
W	5.78	14.38	.08	14.00	16.24
TOTAL	299.88	375.41		252.09	278.95
GROUP AVERAGE	14.28	17.87		12.00	13.28

TABLE 5

SYSTEMATIC ERROR AND STANDARD DEVIATION OF

PER CENT RATING ERROR FOR OPERATION "B"

ENGI-	SYSTEMATIC ERROR		SIG. LEVEL	STANDARD DEVIATIONS	
NEER	OPERATION	FILM	BETWEEN MEANS	OPERATION	FILM
A	11.94	11.29	.90	9.66	12.19
B	20.75	28.45	.13	14.13	11.83
C	17.54	18.86	.70	9.06	9.93
D	24.85	15.02	.12	14.92	19.81
E	18.20	26.89	.025	12.33	10.07
F	17.72	30.70	.02	13.77	14.65
G	24.65	16.94	.08	10.56	11.68
H	18.29	30.97	.70	11.68	13.47
I	28.75	33.80	.41	21.16	16.03
J	25.83	40.10	.82	13.20	14.30
K	33.63	39.56	.63	12.22	14.60
L	19.57	19.14	.59	17.46	20.14
M	26.65	21.09	.37	19.11	13.68
N	31.98	39.78	.90	18.73	18.44
O	14.90	20.92	.26	12.01	16.15
R	18.42	26.37	.18	9.23	16.17
S	19.76	24.30	.26	11.26	10.46
T	18.72	23.17	.82	12.68	13.75
U	12.29	31.39	.30	16.80	11.21
V	14.83	36.31	.001	11.93	15.36
W	12.29	24.21	.51	15.47	11.87
TOTAL	431.56	559.26		287.37	296.42
GROUP AVERAGE	20.55	26.63		13.68	14.11

TABLE 6

RESULTS FROM ANALYSIS OF VARIANCES FOR BOTH OPERATIONS

SOURCE OF VARIANCES	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN MEAN SQUARES	SIGNIFI-CANCE
O	1	12,829,234.1	12,829,234.1	**
E	1	5,506,540.8	5,506,540.8	*
R	20	346,672,855.0	17,333,642.75	***
OE	1	472,554.8	472,554.8	---
OR	20	481,023,166.0	24,051,158.3	**
ER	20	391,705,712.0	19,585,285.6	**
OER	20	130,808,979.0	6,540,448.95	
TOTAL	83	1,370,019,041.7		

* indicates a significance level of 5%
** indicates a significance level of 1%
*** indicates a significance level of 0.1%
--- indicates interaction is insignificant or non-existent

O represents Operations
E represents Environment
R represents Raters
OE represents Interaction Between Operations and Environment
OR represents Interaction Between Operations and Raters
ER represents Interaction Between Environment and Raters
OER represents Residual or Experimental Error

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The objectives of this thesis were to investigate the differences between time study rating of actual operations and the rating of film records of the same performances previously rated from direct observation. A group of twenty-one experienced time study engineers were used as experimental subjects.

Conclusions that can be drawn from the study are:

1. There is some difference in rating of films as compared to rating of actual operations. However, there was insufficient evidence to say conclusively that this difference was significant. Of forty-two test pairs of rating errors (actual operation versus film) only five indicated differences that could not be ascribed to chance at the five per cent significance level. The analysis of variance indicates a significance due to rating of film as compared with the rating of actual operations at the five per cent level of significance.
2. Rating of film presentations is likely to result in a slightly higher average rating error than rating of the actual operation. The average rating error

for the test group was higher for the film rating than for the rating of the actual operation for both operations included in this research. These differences were not evaluated for significance, hence, only intuitive conclusions can be presented.

3. The differences between rating film and rating of the actual operation is likely to be related to the particular operations involved. The analysis of variance indicated a variance contribution due to the operation which was significant at the one per cent level. This result could have been caused, at least in part, by the nature of the criterion values used to evaluate the rating errors. The correct rating for operation "A" was based upon a standard developed and successfully used in previous work. The correct rating for operation "B" was developed by the author using the MTM predetermined motion time system. There was no way to evaluate the difference in level of normal performance represented by these two "correct" values.

4. Individual raters are likely to perform differently in their rating of film as compared with actual operations. The present study indicated a variance contribution due to the rater which was significant at the 0.1 per cent level. This may have been caused in part by individual differences in abilities, or variation in rating consistency. A sig-

nificant variance contribution for the Operation-Environment and Environment-Rater factors at the five per cent level is additional support for this conclusion. The experimental procedure did not allow the gathering of data to investigate individual rater consistency.

5. The test subjects displayed a tendency to over-rate slow performances and to under-rate fast performances.

Recommendations

It is recommended that time study engineers receive rating training on the factory floor with an experienced time study engineer instead of in the class room using rating films. This would give more realistic training and improve accuracy of rating.

It is also suggested that further analysis of this problem would be profitable. Future work should allow for replication of experimental data and evaluation of the consistency of individual rater performances.

APPENDIX I

ELEMENTAL DESCRIPTION

Operation "A"

Element No.	Left Hand	Right Hand
1	Same as right hand.	Reach for, grasp and move grill to frame, position to frame, release grill.
	Same as right hand.	Reach for, grasp and move grill to frame, position to frame. Release grill.

<u>Element 1 ends with Left and Right Hands release grill.</u>

Element No.	Left Hand	Right Hand
2	Same as right hand.	Reach for, grasp and move insert to grill, regrasp insert, position to grill, turn 60^{o}, release.
	Same as right hand.	Reach for, grasp and move insert to grill, regrasp insert, position to grill, turn 60^{o}, release.

<u>Element 2 ends with Left and Right Hands release insert.</u>

Element No.	Left Hand	Right Hand
3	Reach for, grasp and move knob to front of grill.	Reach for, grasp and move brush to front of grill.
	Regrasp knob and hold.	Apply glue to knob.
	Move knob to grill, position to grill, release.	Hold brush.
	Reach for, grasp and move knob to front of grill	Hold brush and dip in jar.
	Regrasp knob and hold.	Apply glue to knob.
	Move knob to grill, position to grill,release.	Hold brush.

ELEMENTAL DESCRIPTION

Operation "A"

Element No.	Left Hand	Right Hand
	Reach for, grasp and move knob to front of grill.	Hold brush and dip in jar.
	Regrasp knob and hold.	Apply glue to knob.
	Move knob to grill, position to grill, release.	Hold brush.
	Reach for, grasp and move knob to front of grill.	Hold brush and dip in jar.
	Regrasp knob and hold.	Apply glue to knob.
	Move knob to grill, position to grill, release.	Move brush to jar, position in jar, release.

Element 3 ends with Right Hand release brush.

Element No.	Left Hand	Right Hand
4	Reach for, grasp and move frame to side of fixture, release.	Move to frame, grasp and move frame to side of fixture, release.

Element 4 ends with Left and Right Hands release frame.

ELEMENTAL DESCRIPTION

Operation "B"

Element No.	Left Hand	Right Hand
1	Same as right hand.	Reach for, grasp and move bolt to fixture, regrasp bolt, position to fixture, release.

Element 1 ends with Left and Right Hands release bolt.

Element No.	Left Hand	Right Hand
2	Same as right hand.	Reach for, grasp and move first plate to fixture, position plate in fixture, release.
	Same as right hand.	Reach for, grasp and move second plate to fixture, position plate in fixture, release.

Element 2 ends with Left and Right Hands release plate.

Element No.	Left Hand	Right Hand
3	Same as right hand.	Reach for, grasp and move washer to bolt, position on bolt, release.
	Same as right hand.	Reach for, grasp and move nut to bolt, regrasp, position on bolt and turn 360^{o}, release.

Element 3 ends with Left and Right Hands release plate.

Element No.	Left Hand	Right Hand
4	Same as right hand.	Reach for, grasp, and move power wrench to first nut, position gun on nut, run up nut.
	Same as right hand	Disengage wrench from nut, move to left hand nut, position gun on nut, run up nut.

ELEMENTAL DESCRIPTION

Operation "B"

Element No.	Left Hand	Right Hand
	Same as right hand.	Disengage wrench from nut, move gun to overhead position, release.

Element 4 ends with Left and Right Hands release power wrench.

5	Same as right hand.	Move to, grasp and move assembled plates to tote box, release.

Element 5 ends with Left and Right Hands release plates.

APPENDIX II

METHODS-TIME MEASUREMENT ANALYSIS OF OPERATION "B"

Element NO.	Left Hand	Right Hand	TMU
1	Same as right hand	Reach for bolt in bin A^1 R20C	19.8
		Grasp bolt 4B	9.1
		Move bolt to fixture M8B	7.2
		Regrasp bolt G2	5.6
		Position bolt in fixture P2SSE	46.5
		Release bolt RL1	1.7
2	Same as right hand	Reach for 1st.plate R8"B	10.1
		Grasp plate 1B	3.5
		Move plate to fixture M8"C	11.8
		Pos.plate in fixture P3SSD	52.1
		Release plate RL1	1.7
3	Same as right hand	Reach for 2nd plate R10$\frac{1}{2}$B	11.8
		Grasp plate 1B	3.5
		Move plate to fixture M10$\frac{1}{2}$C	13.9
		Pos.plate in fixture P3NSD	52.1
		Release plate RL1	1.7
3	Same as right hand	Reach for washer bin B^1R8D	11.5
		Get washer 4B	9.1
		Move washer to bolt M8C	11.8
		Pos. washer on bolt P2SE	16.2
		Contact release RL2	0
	Same as right hand	Reach for nut bin C^1 R8D	11.5
		Grasp nut 4B	9.1
		Move nut to bolt M8C	11.8
		Regrasp nut G2	5.6
		Position nut on bolt P2SE	16.2
		Turn nut 360°	18.8
		Release hand RL1	1.7

METHODS-TIME MEASUREMENT ANALYSIS OF OPERATION "B"

Element No.	Left Hand	Right Hand	TMU
4	Same as right hand	Reach pwr.gun above fixt.R12A	9.6
		Grasp gun G5	1.7
		Move to right hand nut 12"M12C	10.0
		Pos.gun over R.H. nut P3SE	43.0
		Run up nut 750 RPM	13.8
		Disengage wrench from nut	11.8
		Move wrench to L.H. nut M3½C	3.9
		Pos. gun over L.H. nut P3SE	43.0
	Same as right hand	Run up nut 750 RPM	13.8
		Disengage wrench from nut	11.8
		Move gun 8" above fixture	7.2
		Release gun RL2	0
5	Same as right hand	Move to plate assy. M8B	7.2
		Grasp finished assy. 1B	3.5
		Move assy. to tote box M12B	13.4
		Release fingers	1.7
		Total TMU's	570.8

Convert to standard minutes by multiplying by .0006 minutes per TMU.
This equals 570.8 x .0006 = .342 standard minutes.

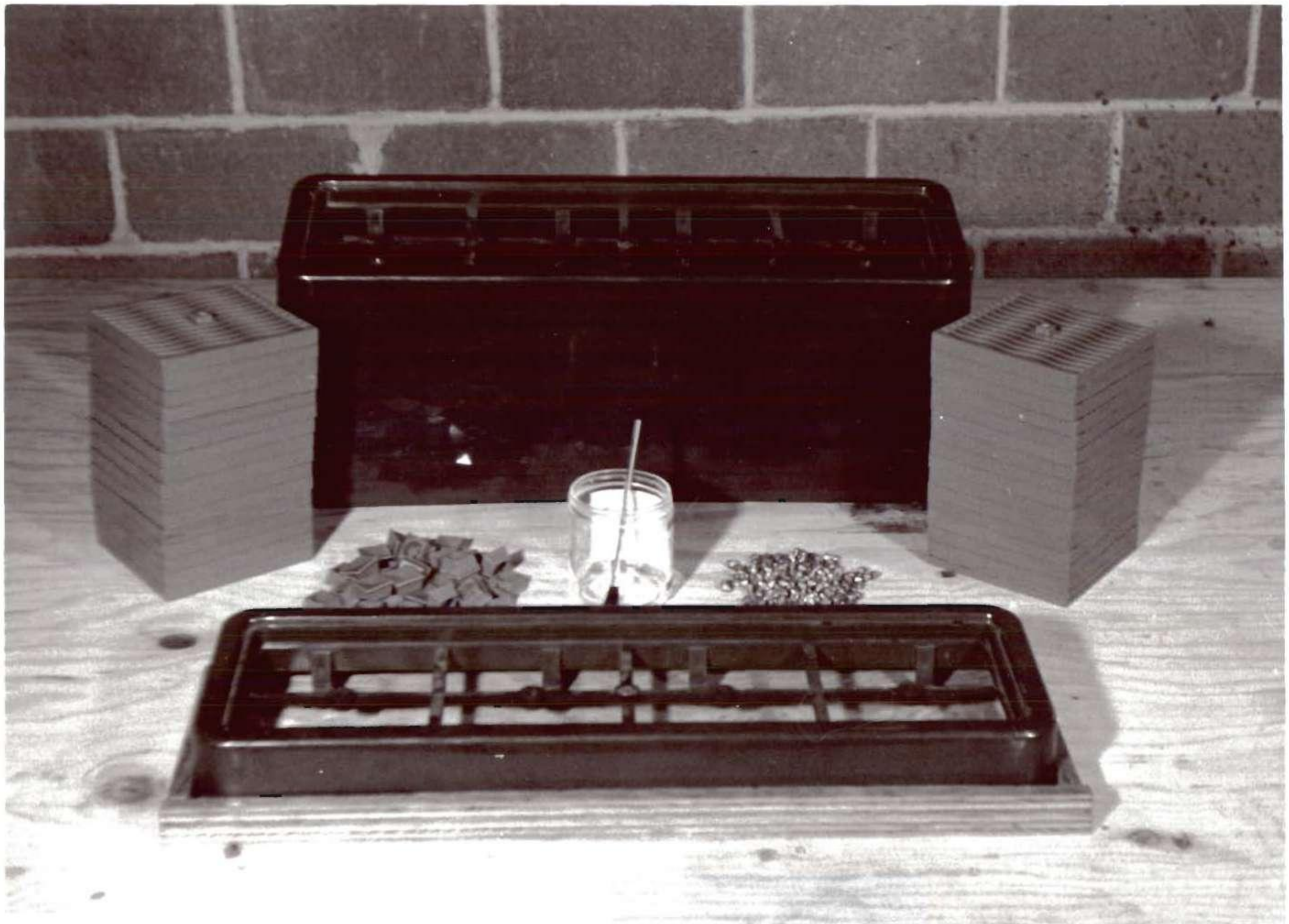

FIGURE 4. CLOSE UP OF AIR CONDITIONER FRONT ASSEMBLY

FIGURE 5. OVERALL LAYOUT OF AIR CONDITIONER FRONT ASSEMBLY

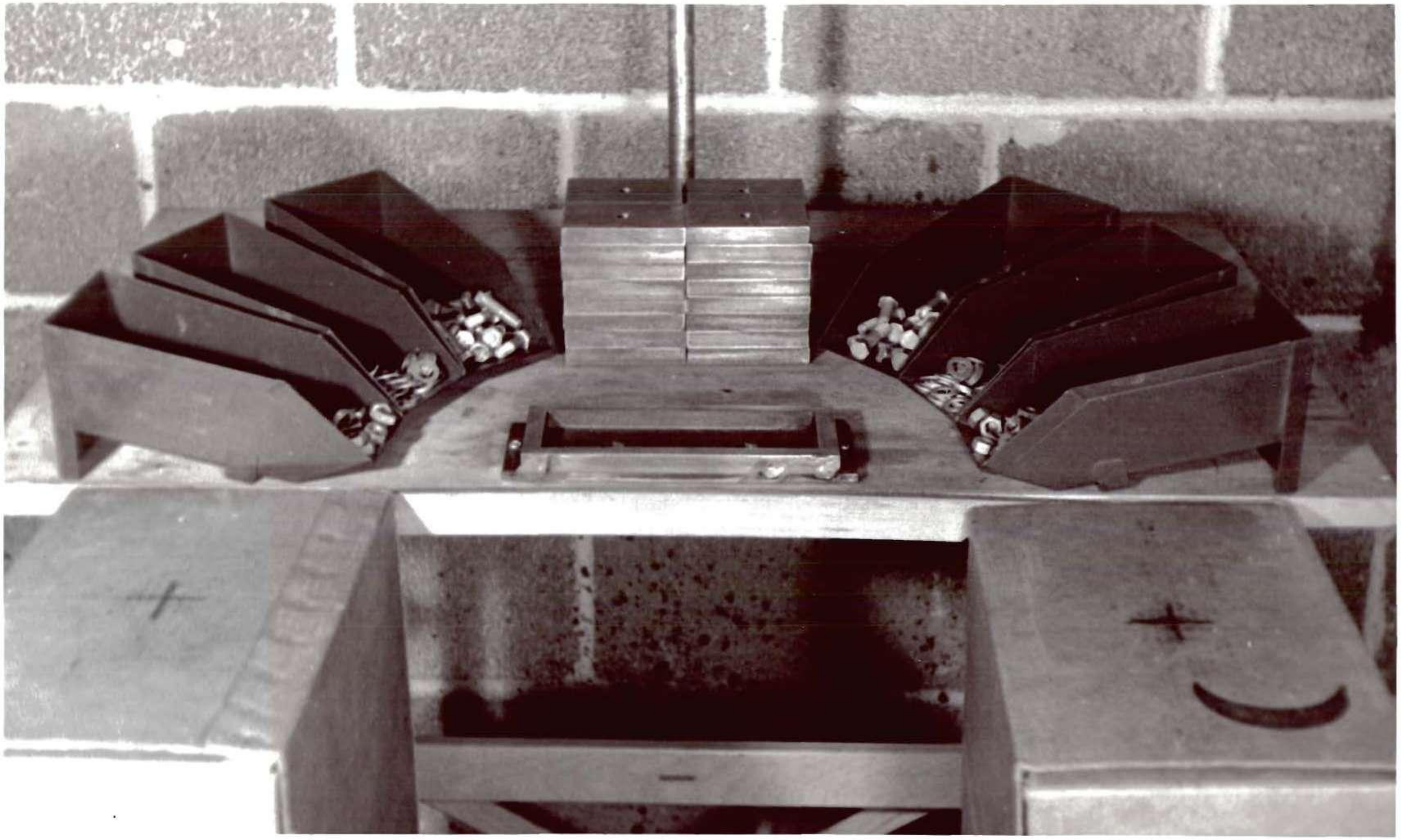

FIGURE 6. CLOSE UP OF COLD ROLLED STEEL PLATE ASSEMBLY

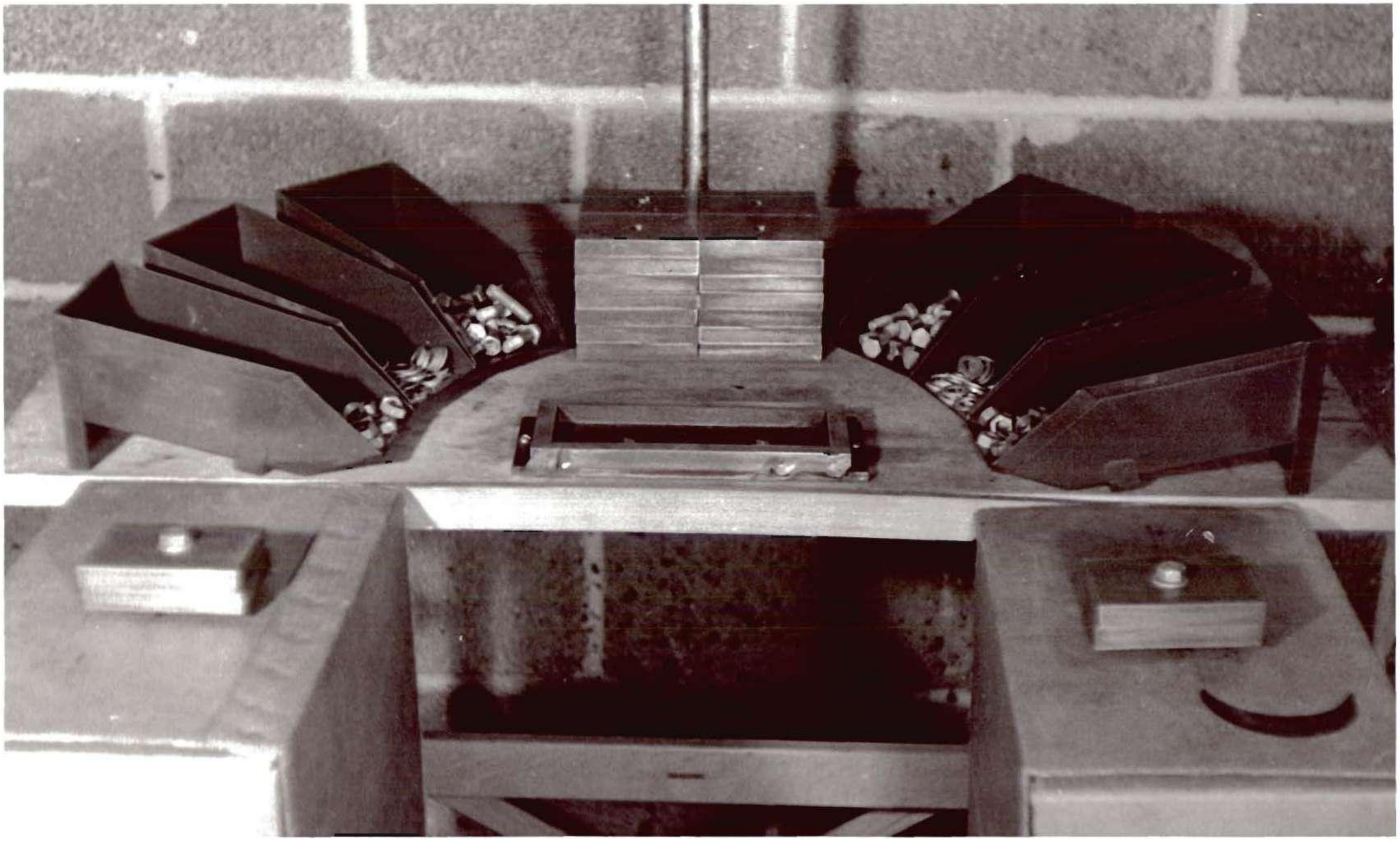

FIGURE 7. CLOSE UP WITH ASSEMBLED PLATES ON TOTE BOX

APPENDIX IV

SAMPLE CALCULATIONS FOR STUDENT'S T-TEST

$$\text{Student's } t = \frac{\bar{X}_o - \bar{X}_f}{\sqrt{\frac{S_o^2 + S_f^2}{n}}}$$

$n = 15$; $S_o^2 = 169.67$; $S_f^2 = 156.05$; $\bar{X}_o = 15.75$; $\bar{X}_f = 32.12$

Degrees of freedom $= n_1 + n_2 - 2 = 15 + 15 - 2 = 28$

For Engineer I:

$$t = \frac{15.75 - 32.12}{\sqrt{\frac{169.67 + 156.05}{15}}} = \frac{-16.37}{\sqrt{21.71}} = -3.052$$

Reject hypothesis if t is less than -2.05 of if t is greater than 2.05 at the 0.05 level of significance. Therefore, reject the hypothesis that the means are equal.

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